BALLOONS AND VOYAGES IN THE AIR.
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BALLOONS AND VOYAGES IN THE AIR.*

It is an interesting speculation whether man, the creature of the earth, can ever attain to the empire of the air, as he has already attained to the empire of the sea. There is nothing unreasonable in the expectation. As a matter of science the laws that govern the motion of heavy bodies in the atmosphere are sufficiently well known, and as a matter of experience and analogy nothing can be more to the purpose than the example of the birds. Hence there has long been a common belief that we may, some time, be able to transport ourselves at pleasure through the air as we now do on the water. The author of the 'Botanic Garden,' writing in 1791, when the steam-engine was beginning to develop its wondrous powers, but long before it had been applied to locomotion of any kind, uttered the well-known prediction—

> 'Soon shall thy arm, UNCONQUERED STEAM, afar
> Drag the slow barge, or drive the rapid car;
> Or on wide-waving wings, expanded, bear
> The flying chariot through the fields of air!'

Two-thirds of the prophecy have been fulfilled; he would be a bold man who would pronounce the fulfilment of the remainder impossible.

* 1. *Description des Expériences de la Machine Aérostatique de MM. de Montgolfier.* Par M. Faujas de St. Fond. Paris, 1783.
2. *Aeronautica.* By Monck Mason, Esq. London, 1838.
3. *Les Ballons et les Voyages Aériens.* Par F. Marion. Paris, 1867. (The same in an English edition.)
4. *Voyages Aériens.* Par T. Glaisher; Camille Flammarion; W. de Fonvielle; et Gaston Tissandier. Illustrés d'après les croquis d'Albert Tissandier. Paris, 1870. (The same in an English edition, edited by T. Glaisher. London, 1871.
5. *En Ballon, pendant le Siège de Paris.* Par Gaston Tissandier. Paris, 1871.
6. *Les Ballons dirigeables.* Par Gaston Tissandier. Paris, 1872.
7. *Reports of the British Association for the Advancement of Science.* London, 1862 to 1866.
8. *Comptes-rendus des Séances de l'Académiedes Sciences.* Paris, 1870 and 1872.

In aerial travelling there are two distinct conditions to be fulfilled. First, there must be a command of *vertical* motion; the force of gravity must be for the time counteracted, and the heavy body must have a capability of floating, or rising, or falling at pleasure. Secondly, there must, in addition to this, be a power of *horizontal* translation through the air.

Both these effects are well produced by a bird, through the mechanical action of its wings; and hence the most natural attempt at aerial locomotion has been by trying to imitate the bird, or to *fly*. There is much to be said in favor of this attempt, for although there is little hope that a human being can ever take to himself wings, yet the possibility of constructing a flying machine, if a very light motive power can be obtained, is hardly to be doubted. Hitherto, however, no attempts of this kind have given even a prospect of success; and as our object now is rather to show what has been done than to speculate on what is possible, we will turn to another mode by which aerial locomotion has been more successfully aimed at, namely, by means of the *balloon*. We propose to trace the history of this ingenious invention—to describe its present condition—to dwell on some important purposes it has served—and finally to investigate what promise it offers of increased utility.

It is not clear when the idea first arose that it would be possible to make a body ascend from the earth by giving it a less specific gravity than the air. One Francis Lana,* in 1670, proposed to exhaust spheres of thin copper for this purpose, but he never attempted to carry out his proposal. The discovery of hydrogen rendered the idea more practicable. Cavendish, in 1766,† showed that the gas known as 'inflammable air' had a specific gravity much less than that of the atmosphere; and Dr. Black, lecturing in 1767 or 1768, explained that, as an obvious consequence of Cavendish's discovery, if a very light bladder were filled with this gas, it would ascend. Tiberius Cavallo attempted the experiment; he could not find any envelope sufficiently light and impermeable, but he succeeded in blowing hydrogen soap-bubbles, which mounted vigorously aloft; and these, the first balloons, were described fully by him in a paper read before the Royal Society, 20th June, 1782.*

It was not, however, in this way that the balloon came practically into existence; its inventors proceeded on a different principle. Instead of using a new fluid lighter than air, they hit upon the idea of altering the density of the air itself by the action of heat. These ingenious men, Joseph and Etienne Montgolfier, whose names are indissolubly connected with aerostation, were the sons of a rich paper maker at Annonay, in the province of the Vivarais. It seems they were fond of physical investigations: Joseph particularly had studied the constitution of vapor and clouds, and he saw that temperature had much to do with these phenomena. He had convinced himself by experiment that the application of heat would rarefy air so as to reduce its specific gravity considerably, and it occurred to him to try whether, by enclosing such heated air in a suitable envelope, he could make a kind of *artificial cloud* which would float in the atmosphere. In November 1782, when staying at Avignon, he made the experiment with a light bag of thin silk, which to his great gratification rose to the ceiling.

On his return home, the brothers worked together; and after another successful trial they made a public exhibition of their invention, at a meeting of the *Etats particuliers* of the province, on the 5th of June, 1783. Etienne has left on record a description of this first large balloon; it was about thirty-five feet diameter, and had a large ascending power; it rose some thousands of feet, and travelled a mile and a half horizontally.

The news of this experiment soon spread to the capital, exciting great wonder and enthusiasm, and the Academy named a Commission to inquire into the facts. But in the meantime attention had become attracted to the other mode of giving levity by hydrogen gas. A young man, named Charles, favorably known as a professor of physics in Paris, had been experimenting with this substance in his laboratory, and conceiving it to have advantages over Montgolfier's heated air, he pro-

* Prodromo, o saggio di alcune invenzioni nuove, &c. Brescia, 1670.

† 'Phil. Trans.' vol. lvi, p. 152.

* 'The History and Practice of Aerostation.' By Tiberius Cavallo, F.R.S. London, 1785.

posed to substitute it in balloons. He called to his aid two practical mechanicians, the brothers Robert, and constructed a silk balloon of twelve feet diameter. After some difficulty in procuring a sufficient quantity of gas (the manufacture of which, on any large scale, was quite new) it was filled, and transported to the Champs de Mars, where the ascent took place on the 27th of August, 1783.

After rising to a great height and travelling many miles, the expansion of the gas caused a small leak in the balloon, and it came down near a village. The inhabitants were frightened beyond measure, particularly when they were told by two monks that it must be some demon from another world. Formal religious exorcisms were recited, but no one dared approach the monster, for the bounds it gave when blown by the wind, the noise of the escaping gas, and its fetid odor, kept up the dread illusion. At length it was fired at, and further wounded, and when it had become empty and still, the mob rushed upon it with staves and forks and tore it to atoms.

The Montgolfiers, however, had not been idle. The Academy had reported favorably of their invention, and the brothers were called on to exhibit an ascent before Louis XVI. at Versailles. This came off with great pomp and ceremony on the 19th of September.

As the power of balloons had now been fully established, it was proposed that some person should make an ascent, if any one could be found bold enough to face a voyage that required more of the *æs triplex* than the first expedition on the merciless ocean. A volunteer appeared in the person of a young man of good position, named Pilâtre des Roziers, who after making some tentative ascents with the balloon tied to the ground, offered to undertake the journey. It involved some danger: a fall, fire, cold, unknown perils amongst the clouds, and the difficulties of descending, were all matters of grave apprehension; and the King, after consideration, forbade M. de Rozier's ascent, and proposed, instead, that two condemned criminals should take their places in the car. Pilâtre was indignant at the idea of 'such an honor being conferred on vile malefactors,' and he remonstrated so energetically that the King gave way; and on the 21st of November,* 1783, the daring volunteer, accompanied by the Marquis d'Arlandes, left the earth on the first aerial voyage ever undertaken by a human being. A full account of the journey is on record in two documents—one a formal *procès-verbal*, drawn up by eight members of the Academy, the other a letter by the Marquis. The balloon was seventy feet high, and forty-six feet in diameter; it rose to a height of three thousand feet, remained in the air nearly half an hour, and descended in the environs of Paris, without the aeronauts having experienced the slightest inconvenience. Among the signatures to the *procès-verbal* was that of Benjamin Franklin, then on a mission to France; and it is reported that when he was asked his opinion of the invention, he replied, 'C'est l'enfant qui vient de naitre!'

Thus the Montgolfiers not only made the first balloon, but, as was their due, they had the honor of sending up the first aeronaut. The genius and enterprise, however, of their rival, young Charles, soon made themselves apparent by his announcing a personal ascent on his hydrogen principle; and as this principle ultimately became established to the exclusion of the other, Charles's experiments possess the interest of being the more accurate type of our modern aeronautic system. Associating himself again with the Messrs. Robert, he prepared a balloon thirty feet diameter, introducing many important arrangements of detail, which, from their perfection of design and ingenuity of construction, have remained almost unaltered to the present time. The balloon was to ascend on the 1st of December, 1783, from the great basin in front of the Tuileries, and Charles made up his mind to occupy the car; but, while the balloon was filling, it was announced that the King again opposed the proceeding. Charles went to the Minister and protested, declaring that, though his Sovereign might be master of his life, he was not master of his honor, and that he could not break a solemn promise made to the nation. The King yielded to this bold argument, and the

* The Marquis's letter says 21st October; but it is dated 28th November, it has every appearance of having been written soon after the ascent, and as the *procès-verbal* gives November, the word October is probably a clerical error.

prohibition was withdrawn. Shortly afterwards another difficulty arose by a hostile demonstration on the part of the Montgolfierists—for the public had split up into two rival factions, the partisans of heated air and gas respectively. Charles, seeing this, stepped up to Etienne Montgolfier, and presented him with a small pilot balloon, saying, 'C'est à vous, Monsieur, qu'il appartient de nous montrer la route des cieux.' The good taste and delicacy of this proceeding were testified to by shouts of applause, and the rivalry was at once at an end. The day was set apart as a great fête, and it was said that three-fourths of the inhabitants of Paris were present. Charles took with him the younger Robert, but dropped him near l'Ile Adam, and re-ascended alone, when he gained a height of nearly 10,000 feet; and after making many interesting scientific observations, he descended safely near the wood of La Tour du Lay.

The enthusiasm created by the aeronautic experiments of 1783 was immense. To quote M. Marion's excellent little work:*

'Nobles and artisans, scientific men and *badauds*, great and small, were moved with one universal impulse. In the streets the praises of the balloon were sung; in the libraries models of it abounded; and in the salons the one universal topic was the great machine. In anticipation the poet delighted himself with bird's-eye views of the scenery of strange countries; the prisoner mused on what might be a new way of escape; the physicist visited the laboratory in which the lightning and the meteors were manufactured; the geometrician beheld the plans of cities and the outlines of kingdoms; the general discovered the position of the enemy, or rained shell on the besieged town; the police beheld a new mode in which to carry on the secret service; Hope heralded a new conquest from the domain of Nature, and the historian registered a new chapter in the annals of human knowledge.

'It was not merely the blue sky above us, not merely the terrestrial atmosphere, but the vast spaces through which the worlds move, that were to become the domain of man. The gates of the Infinite seemed to be swinging back before his advancing step. The moon, the mysterious dwelling-place of men unknown, would no longer be inaccessible. The planets that revolve round the sun, the flying comets, the most distant stars, these formed the field which was to lie open to investigation.'

It was not to be expected that a volatile nation like the French would allow such a subject to become popular without making it the theme of endless jokes and witticisms. Some of these are worth recording.

In one ascent, snow fell on the balloon; and the wits wrote,—

'Fiers assiégeants du séjour du tonnerre,
Calmez votre colère!
Eh! ne voyez-vous pas que Jupiter tremblant
Vous demande la paix par son pavillon blanc?'

Apropos of an unsuccessful attempt at Lyons with a balloon called 'Le Globe'—

'Vous venez de Lyon; parlez-vous sans mystère?
Le Globe est-il parti? Le fait est-il certain?
Je l'ai vu. Dites nous, allait-il grand train?
S'il allait—Oh, monsieur, il allait *ventre à terre!*'

Of an aeronaut who had cheated the public:—

'Si par son vol il peut escalader la lune,
Il fera comme un autre, *en volant*, sa fortune!'

A large number of caricatures appeared, some very witty, and some very coarse, exhibiting, as an author says, 'la vraie saveur du bon sel français.' In one, a ludicrous mode was shown of filling a balloon with mephitic gas, by the aid of a large number of people, the title being 'La fortune des gens venteux!' In another, alluding to abortive attempts, a 'Moyen infaillible d'enlèvement des ballons,' was exhibited in the shape of ropes and pulleys. One of these failures was by a person named l'Abbé Miolan, at the Luxembourg; the crowd, after waiting some hours, rushed in and destroyed the balloon, when the witty Parisians found out that the anagram of the Abbé's name was *ballon abîmé*.

In one of Gay-Lussac's ascents, being desirous of rising very high, he threw out many superfluous things, and among them a common deal chair, which fell into a field where a peasant girl was at work; the balloon was invisible, and the only explanation possible was, that the chair had fallen from heaven. Much surprise was expressed at the uncomfortable accommodation provided for the angels and archangels, but the miracle was ultimately explained.

Many objections were raised to the new invention, which was denounced as an impious attempt to improve on the work

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* The English translation of this requires correction, the rendering of the French measures being in many cases wrong.

of the Creator: it was urged that female honor and virtue would be in continual peril if access could be got by balloons at all hours to the windows of the houses; and politicians objected that if the path of air were to be made free, all limits of property and frontiers of nations would be destroyed; a sentiment which was countenanced by a serious proposal to invade England with an army descending from the skies.

The English were somewhat backward in their notice of balloons, and it was said of them,

> 'Les Anglais, nation trop fière,
> S'arrogent l'empire des mers;
> Les Français, nation légère,
> S'emparent de celui des airs.'

A short excursion was made at Edinburgh, in a Montgolfier, by a Mr. Tytler, on the 27th of August, 1784;* but the earliest ascent in Great Britain which attracted attention was a voyage in a gas balloon, on the 15th of the following month, by Vincenzo Lunardi, secretary to the Neapolitan Ambassador. He ascended from Finsbury, in the presence of a large concourse of spectators, among whom was the Prince of Wales, and came down safely on a spot of rising ground about four miles north of Ware. †

* 'Gentleman's Magazine,' vol. liv. part ii. p. 709.

† A rough stone, erected to mark the place, may still be seen in a field at Standon Green End, on the estate of Mr. A. G. Puller. It bears a small triangular brass plate, engraved with two views of the balloon, and with the following curious inscription:—

Let Posterity Know
And Knowing be Astonished,
That
On the 15 Day of September, 1784,
Vincent Lunardi of Lucca in Tuscany,
The First Aerial Traveller in Britain,
Mounting from the Artillery Ground
in London,
And
Traversing the Regions of the Air
For Two Hours and Fifteen Minutes
In This Spot
Revisited the Earth.
On this Rude Monument
For Ages be Recorded
That Wonderous Enterprise
Successfully Atchieved
By the Powers of Chemistry
And the Fortitude of Man:
That Improvement in Science
Which
The Great Author of all Knowledge,
Patronizing by his Providence
The Invention of Mankind,
Hath Graciously Permitted
To Their Benefit
And His Own Eternal Glory.

Traditions of the event are preserved in the neighborhood; one of the rude fathers of the hamlet, who showed us the stone, boasted of having known a woman who helped to hold down the balloon, and pointed out the tree to which it was secured. The plate is in very bad condition, and if Lunardi's wish is to be fulfilled, we commend his 'rude monument' to the care of the landowner.

Three circumstances related by Lunardi * will show the public excitement produced. A gentlewoman who saw some article drop from the car, supposed it was the aeronaut, and died of the fright. A jury were considering the verdict to be given on a criminal, indicted for a capital offence, when the balloon being in sight, the Court adjourned to look at it, and the jury to save time acquitted the prisoner; the judges afterwards remarking to Lunardi, that though he had caused the loss of one life, he had saved another. A Cabinet Council also broke up, in order that the King, with Mr. Pitt and other ministers, might watch the balloon through telescopes prepared for that purpose: the King remarking, "we may resume our deliberations at pleasure, but we may never see poor Lunardi again."

Shortly after this, an experienced French aeronaut, Blanchard, brought a balloon to England, and on the 7th of January, 1785, he performed the hazardous feat of crossing the Channel. He was accompanied by Dr. Jeffries, an American, who afterwards published an account of the voyage. † They started from Dover heights at about mid-day, with a light north-westerly wind. During the passage, by loss of gas, the balloon descended several times nearly to the water level, and to keep themselves from drowning they threw out first their ballast, and then every other loose article, including all their provisions, a great part of their clothes, and their anchors. At last they reached the shore, and landed safely in the forest of Guines, near Calais. Blanchard gained much honor by this expe-

* 'An Account of the First Aerial Voyage in England.' In a series of Letters. By Vincent Lunardi, Esq. London, 1784.

† 'A Narrative of the Two Aerial Voyages of Doctor Jeffries with Mons. Blanchard.' By John Jeffries, M.D. Presented to the Royal Society, and read before them, January 1786. London, 1786.

dition, but he did not escape the wit of the Parisians, who nicknamed him "Don Quichotte de *la Manche*."

The French were jealous of the crossing having been first effected from the cliffs of perfidious Albion, and the enterprising Pilâtre des Roziers determined to attempt the passage from the French shore. The story is a romantic and melancholy one. He had many difficulties and discouragements, but he had fallen in love with an English girl at Boulogne, and as she urged him to make the experiment, he did so, in spite of the warnings of his friends. He ascended on the 15th of June, 1785, with a companion, and they were carried at first over the strait; but the wind changing, they were brought back to the land. They were hanging within sight of Boulogne when the balloon took fire, and the unhappy aeronauts falling to the earth, were both killed. The young lady who had contributed to the catastrophe, and who was probably a witness of it, fell into horrible convulsions, and died a few days after her lover.

Many other aeronauts have fallen victims to their hazardous occupation; among them was Madame Blanchard. At a Parisian fête on the 6th July, 1819, she had attached to her car a large mass of fireworks, which she set light to when at a great height. When these were extinguished, a bright flame shot up into the air: the spectators at first thought it was part of the entertainment, but it was soon discovered that the gas of the balloon was ignited. As she descended she called for help, and, as she retained her presence of mind, she might have been saved, but the car, in dragging, caught a chimney, which threw her down to the pavement below and killed her on the spot.

We also read of a narrow escape from a madman (an Englishman, of course), who, when at a great height, took out a knife and began to cut the cords that held the car, saying he should like to try the sensation of a fall. The aeronaut opened the valve with all his might, and contrived to delay the experiment till they touched the ground.

It was not uncommon for persons of rank to take seats in the car, either as managers or passengers. The future Charles X., the Comte d'Artois, and Philippe Egalité, were among this number, and the latter nearly lost his life by the trial of some new apparatus. There were many jokes at his expense, and it was said, 'Il avait voulu se mettre au-dessus de ses affaires.'

The English aeronauts have not been behind their Continental brethren for skill and enterprise. The Sadlers, father and son, were renowned for their courage. James, the father, made an ascent from Oxford as early as 1784; and on the 1st of October, 1812, he attempted to cross the Irish Channel from Dublin to Liverpool. But he met with adverse winds, and after much buffeting about, he was obliged to drop into the sea, and was picked up by a boat that fortunately was near, the captain being obliged to run his bowsprit through the balloon to free him. His son, Windham Sadler, accomplished the passage from Dublin to Holyhead on the 22nd of July, 1817. On one of his ascents the net broke and the car began to slip away, when he saved himself by tying the neck of the balloon round his body. He was unhappily killed on the 29th of September, 1824, while descending in a gale, by striking against a house near Blackburn, in Lancashire.

Mr. Green, another of our most celebrated aeronauts, was born the year after the invention of balloons, and died only a few years ago. He made nearly 1400 ascents; he crossed the sea three times, and twice fell into it. He took up 700 persons, among whom were 120 ladies, and many persons of high rank. On one occasion he ascended sitting on a favorite pony, suspended to the hoop in the place of the car; the animal, who had been trained at Astley's, did not manifest the least uneasiness, but ate freely during the excursion some beans given him by his rider.

A voyage made by Mr. Green to the centre of Germany is one of the most memorable on record. The balloon was 50 feet diameter, containing 85,000 cubic feet of gas, and the party consisted of Mr. Green, Mr. Monck Mason (who, in his 'Aeronautica,' has given a full account of the voyage), and Mr. Robert Holland, who provided the funds. They ascended from Vauxhall Gardens on the 7th of November, 1836, at half-past one P.M., and, crossing the Channel, passed to the eastward during the night, and the next morning saw large tracts of snow, which they thought might be the boundless plains of Poland or the inhospitable

steppes of Russia. This determined them to descend, when they found themselves near Weilburg, in the Duchy of Nassau, having travelled about 500 miles in 18 hours. The balloon afterwards took the name of the Nassau balloon. Mr. Green's principal object in this expedition was the trial of his newly-invented guide-rope (described hereafter), and he considered the success of the experiment as complete.

A larger balloon constructed by M. Nadar, and named the *Géant*, contained above 200,000 cubic feet, equivalent to about 74 feet diameter; the car was a house of two stories, weighing, when full, above three tons. M. Nadar, a man of considerable ability, had adopted the fancy that it was impossible to control the direction of balloons, on account of their lightness and large surface, and he considered he had discovered an important scientific principle, that 'pour lutter contre l'air il faut être plus lourd que l'air.' He instituted a Society to introduce flying machines on this principle, and he proposed to provide it with funds by the excursions of this monster balloon. He ascended at 5.45 P.M., on the 18th October, 1863, from the Champ de Mars, with eight passengers, among whom was a young Montgolfier, the grandson of one of the men of Annonay. At 9 the next morning they descended between Bremen and Hanover. The wind was blowing a hurricane, the two anchors parted, the aeronauts lost the control of the valve, and there ensued a violent dragging for many miles, until the balloon tore itself open on the trees of a wood. The passengers were much hurt, and barely escaped with their lives.* The balloon was afterwards repaired, and exhibited in London and elsewhere, and it made a few more short excursions, but it did not much help the 'plus lourd que l'air' Society.

On the evening of the 31st August, 1874, M. Jules Duruof, a courageous young Frenchman, ascended with his wife from Calais, intending to cross to England. The balloon was, however, carried over the German Ocean, and the aeronauts were rescued the next morning by a Grimsby smack, that happened to be fishing on the Dogger bank, 170 miles off the mouth of the Humber.

The bursting of a balloon in the air, terrible as it is to think of, does not seem necessarily to involve fatal consequences to the aeronauts. In 1808 a balloon, carrying two Italians, burst at a great height; and in 1835 Mr. Wise, an American aeronaut of great experience and enterprise,* met with a similar accident in Pennsylvania; but in both cases the balloon, from its great resisting surface exposed to the air, brought the aeronauts gently down. Mr. Wise, reflecting on these accidents, became so convinced of the efficacy of the resistance, that he afterwards, on several occasions, burst his balloon purposely when high in the air. In 1847 an accident of this kind happened on an ascent from Vauxhall, when Mr. Coxwell and the late Albert Smith were of the party, but no one was seriously hurt. Mr. Glaisher supports Mr. Wise's explanation by facts occurring in his own experience; but he justly remarks that 'it is not a situation to be coveted.'

To provide against cases of this kind, Blanchard introduced the *parachute*, a sort of large umbrella, suspended between the balloon and the car. In ordinary circumstances it was closed, but on falling fast it opened of itself, and by its resistance checked the velocity so materially as to allow of the descent being effected safely. Blanchard tried the first experiment on his dog, and this was so successful, that parachutes were frequently afterwards used by the aeronauts themselves. Garnerin, in October 1797, dropped safely from a height of 2240 feet; and his wife was so skilful in their management, that she once laid a wager she would make one descend on a given spot, which she accomplished with tolerable precision.

On the 24th July, 1837, an enthusiast named Cocking insisted on dropping himself from Mr. Green's balloon, when at a height of 5000 feet above London, in a parachute of his own contrivance, which utterly failed, and the poor fellow was dashed to pieces.

But our readers may wish to form some more definite idea what a balloon is, and

* 'Mémoires du Géant,' par Nadar. Paris, 1865. The most readable and entertaining book we have met with on the subject of ballooning.

* 'A System of Aeronautics.' By John Wise. Philadelphia, 1850.

what sort of operations are involved in a balloon voyage.

First, as to the source of the ascending power. For a long time Montgolfier's system of heated air and Charles's system of light gas were in rivalry. The former was much the simpler; but the hydrogen was difficult and costly to prepare, and the filling of a balloon with it took many days. About 1814 coal gas came into use for lighting towns, and this settled the question by providing an excellent filling material, always to be had at gasworks at a moderate charge. Although six or seven times heavier than pure hydrogen, it was still less than half the weight of air, and therefore would give, with moderate-sized balloons, a fair ascending power; moreover, being less subtle, it was less liable to leak through the stuff of the envelope. Mr. Green was the first to take advantage of this gas, and it has since been almost universally used. The Montgolfier system is quite abandoned, and pure hydrogen is only resorted to in special cases where great power is required.

The ascending force is determined, according to well-known hydrostatic laws, by the difference in weight between the gas and an equal volume of air. An example will make this clear. The standard balloon used in the siege of Paris (of which we shall speak hereafter) was about 50 feet diameter, containing 70,600 cubic feet. The weight of this volume of air would be about 5000 lbs., and the weight of the gas (assuming a sp. gr. of 0.40) would be 2000 lbs. Hence the gross ascending force would be 3000 lbs. The weight of the balloon, net, and car was about 1000 lbs., thus leaving 2000 lbs. available for passengers, dispatches, ballast, and anchoring apparatus. If the same balloon were filled with hydrogen, the weight of the gas would be only 350 lbs., and the disposable ascending force would be 3650 lbs.

The shape is generally spherical, as giving the largest content with the least weight, and the available power of the balloon increases with its size. The bottom of the balloon is not closed, but tapers to form a pipe. This serves for the inflation, and it is left open during the ascent to allow of the escape of the gas as it expands; if it were not for this precaution, the balloon would burst from the increased pressure. At the top of the balloon is fixed the *escape valve*, which consists of two doors or flaps opening inwards and kept closed by springs. To these doors cords are attached, which pass down the centre of the balloon and through the open pipe into the car. The aeronaut has only to pull these cords to open the valves, which allow the gas to escape.

The balloon is covered with a network of fine, strong cord, which, passing down the sides, terminates in a wooden hoop at the bottom. To this hoop the car is suspended by ropes, and thus, by means of the net, the weight is transferred to the top of the balloon, on which the ascending force acts. The car is simply an oblong basket of wicker-work, combining lightness with strength to resist strains or blows.

The balloon has to be provided with several appurtenances necessary for the aerial manœuvres. The most important is *ballast*, which consists of fine sand carried in small sacks; this material when thrown out distributes itself in the air, and so does no damage in falling. Another provision is an anchor or *grappling hook*, intended to catch hold of some object when the balloon approaches the earth, and so to arrest its course. This is attached to a coil of rope that hangs over the side of the car, ready to be disengaged at any moment by cutting a small binding string.

Another article of equipment, in large balloons, is a long rope called the *guide rope*, which is fastened to the hoop and allowed to hang down below the car. This has several important uses. In the first place, when the balloon is so low that the rope trails on the ground, the effect is to take off a portion of the weight which is equivalent to the discharge of so much ballast, and as the lightening increases by the descent of the balloon, a most efficient self-acting check is thus offered to any rapid fall. Secondly, the trailing along the ground also checks more gently than the grapnel the horizontal drift by the wind. Thirdly, the position and angle of the rope, as seen immediately below the car, furnish indications both of the course of the balloon and its height above the ground, which are peculiarly valuable in darkness and fogs; and lastly, it affords the people on the ground something to lay hold of in order to help the aeronaut to descend. The guide rope

is generally from 500 to 1000 feet long, and by means of a small windlass in the car, it may be lengthened or shortened at pleasure. It was invented by Mr. Green, and is the only new feature of importance added to the general design of the balloon as left by Charles in December, 1783.

We may now consider the operations of the voyage. The balloon being filled, the aeronaut carefully examines his ballast, his anchor attachments, and his valve lines, the three great provisions for his safety, and at his signal 'let go' the machine soars into the air. He will have taken in the greatest possible quantity of ballast, so as to leave but little ascending force, and to moderate the velocity of his rise; he can throw more out at any time, and thus can increase his upward speed as he desires. In proportion, however, as he rises, the conditions of the ascending force become changed. The air at higher levels has a reduced pressure, the consequence of which is a tendency of the gas to expand. Hence if the balloon was full at starting, an escape will take place by the tube at the bottom; but it is customary to leave a portion empty to provide for the expansion. Supposing now the ascent to continue, a point will soon be reached where, by the loss of gas, the ascending force will be reduced to an equilibrium with the weight, and at this point the balloon will float horizontally, neither rising nor falling.*

There are other sources of variation in the ascending power. One is, change of temperature: a powerful sun will expand the gas, or, on the other hand, a shower of rain or a deposit of snow will contract it—either of these changes having a corresponding effect on the equilibrium. The alteration of weight, also, by moisture, and the loss of gas by leakage, or by exosmose, or by diffusion in the air through the neck, are all disturbing influences that go on more or less during the voyage.

The aeronaut forms an idea of his height by the inspection of a barometer in the car; and he has it in his power to alter his level as he pleases. If he wishes to ascend, he throws out ballast; if to descend, he opens the valve and lets out gas. But he must be careful not to be too lavish of these means, seeing that his stores of gas and ballast are limited, and that it is absolutely necessary, for the safety of his life, that he should have a fair supply of both left at the time he wishes to regain the earth.

The descent is the most arduous task of the aeronaut, and during which he is most exposed to danger, particularly if the wind be high. Having brought himself tolerably low, he will look out for a favorable place ahead, where he may land easily, the best condition being a free open space, unencumbered by buildings or trees. On approaching this, he will throw out his grapnel, and, if it catches, it will bring him to a stand. He will probably receive a shock or two, but having now a hold on the ground, he may with a vigorous pull at the valve easily accomplish his descent, particularly if friendly helping hands are near. But his anchor may not catch, or may give way, and a strong wind may carry him on. His task is then a difficult one, requiring great nerve and presence of mind. He may see a building or a tree in his way, towards which he is being hurled with fatal force, when his only chance of salvation is instantly to throw out ballast to rise and escape it; after which he must renew his attempt. The swaying of the balloon by the wind when the grapnel has caught, the highly inclined position, requiring him to hold on to avoid being thrown out, the risk of dragging, and many other contingencies, make a descent in a high wind a thing only to be undertaken by very experienced hands.

In some cases balloons, after being inflated, are allowed only to rise a certain height under restraint, being secured to the earth by long cords. These are called *captive* balloons. They have at different periods been fashionable, as affording amusement to the public, and, in some cases, have been of real utility. Two large captive balloons have been made of late years, one at Paris, in 1867, the other in London, in 1868. The Paris one was

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* As an approximate rule, omitting the disturbing influences of temperature, &c., the height in feet to which a balloon will rise, whose capacity in cubic feet = C, and weight in lbs. = W, will be = 27,800 hyp. log. $\frac{C\,(1-s)}{14\,W}$, where s = sp. gr. of gas, air being unity. This formula will also show the effect of discharging ballast, by substituting a diminished value of W. It is said that the last thoughts of Euler were occupied by this problem, the calculations being found on his slate at the time of his death on the 7th Sept. 1783.—'Voyages Aériens' (French edition).

placed in a building adjoining the Exhibition, and it carried twelve persons in the car to a height of about 800 feet. The London captive balloon, installed in Ashburnham Park, Chelsea, was much larger, 93 feet diameter, and containing about 425,000 cubic feet. It was filled with hydrogen gas, and took up thirty-two people at a time to a height of 2000 feet; a steam-engine of 200 horse-power being used to draw it down again. Both these fine balloons were made by M. Henri Giffard, of whom we shall have more to say by-and-by.

It may now be asked of what use are balloons? Almost all writers on the subject have concurred in lamenting that an invention of such high promise should have performed so little. The balloon has been a singular exception to the ordinary course of mechanical discoveries. The steam-engine, machinery, steam navigation, railways, the electric telegraph, photography, iron construction, have all, soon after their introduction, received rapid development; while this art of aerial locomotion, from which so much was expected, has remained just where it was in 1783. Franklin's child has never grown; he is an infant still. The balloon, instead of revolutionising the world, has settled down to the position of a huge toy, and has taken rank with fireworks and monster bands as an attraction to fêtes and holiday amusements, for the mere gratification of idle curiosity.

There have been, however, two purposes of special character to which the balloon has been seriously applied, and in which it has rendered good service, namely, the scientific investigation of atmospheric phenomena, and the art of war.

First, as to the scientific use of balloons. From the time of their invention philosophers have thought them applicable to aerial and meteorological researches, and many ascents have been planned at different times with this view. At the beginning of the present century an aeronaut named Robertson, who is spoken highly of by Arago, made such ascents at Hamburg and St. Petersburg, and about the same date Gay-Lussac and Biot undertook similar experiments at Paris, at the suggestion of Laplace. Messrs. Barral and Bixio, in 1850, and Mr. Welch, of Kew, in 1852, followed in the same track; but the most extensive series of investigations of the kind have been made within the last ten years, at the instance of the British Association, by Mr. Glaisher, of the Greenwich Observatory. He associated himself with our most experienced living aeronaut, Mr. Coxwell, and the ascents were made in a large balloon of 90,000 cubic feet capacity, constructed specially for the purpose. The objects were to make observations at high altitudes on the thermometric, hygrometric, electrical, and chemical condition of the air; on the magnetic force; on the spectrum and solar influences; on clouds and vapors; on aerial currents; on sound; and on any other interesting phenomena that offered themselves. For Mr. Glaisher's results on these points we must refer to his very full official Reports; but he has given to the world a popular account of some of his voyages in the book mentioned on our first page. In the years 1862 to 1866 he made twenty-eight ascents, in one of which he rose to the great height of 37,000 feet, or *seven miles*. At this elevation he lost consciousness, and the cover of his book is ornamented with his picture as he hung over the edge of the car in this critical condition. The following extract, descriptive of 'The High Regions,' will give an idea of Mr. Glaisher's style:—

'Above the clouds the balloon occupies the centre of a vast hollow sphere, of which the lower portion is generally cut off by a horizontal plane. This section is in appearance a vast continent, often without intervals or breaks, and separating us completely from the earth. No isolated clouds hover above this plane. We seem to be citizens of the sky, separated from the earth by a barrier which seems impassable. We are free from all apprehension such as may exist when nothing separates us from the earth. We can suppose the laws of gravitation are for a time suspended, and in the upper world, to which we seem now to belong, the silence and quiet are so intense, that peace and calm seem to reign alone.

'Above our heads arises a noble roof—a vast dome of the deepest blue; in the east may perhaps be seen the tints of a rainbow on the point of vanishing; in the west the sun silvering the edges of broken clouds. Below these light vapors may rise a chain of mountains, the Alps of the sky, rearing themselves one above the other, mountain above mountain, till the highest peaks are colored by the setting sun. Some of these compact masses look as if ravaged by avalanches, or rent by the irresistible movements of glaciers. Some clouds seem built up of quartz, or even dia-

monds; some, like immense cones, boldly rise upwards; others resemble pyramids whose sides are in rough outline. These scenes are so varied and so beautiful, that we feel that we could remain for ever to wander above these boundless planes. . . . . But we must quit these regions to approach the earth; our revolt against gravity has lasted long enough, we must now obey its laws again. As we descend, the summits of the silvery mountains approach us fast, and appear to ascend towards us; we are already entering deep valleys, which seem as if about to swallow us up, but mountains, valleys, and glaciers all flee upward. We enter the clouds and soon see the earth: we must make the descent, and in a few minutes the balloon lies helpless, and half empty, on the ground.'

In addition to Mr. Glaisher's accounts, the work also contains descriptions of balloon voyages by three eminent French aeronauts, Messrs. Flammarion, De Fonvielle, and Gaston Tissandier. M. Tissandier deserves credit for having introduced a new feature into balloon descriptions, by taking up his brother, a practised artist, who has illustrated the balloon adventures and the scenery of the voyages with much skill.*

The most recent scientific ascent was attended with a lamentable result. On the 15th April, 1875, M. Tissandier started from Paris, accompanied by M. Croce-Spinelli, an engineer, and M. Sivel, a naval officer, the object being to make certain observations at high altitudes. The records of the height do not show so great an elevation as that attained by Mr. Glaisher, but either from the effect of the rarefaction, or from the inhalation of gas, M. Tissandier's companions were both suffocated, and he himself narrowly escaped with his life. Is there enough to be learnt at these great elevations to justify the risk they entail?

The application of balloons to the art of war presents great interest, on account of the remarkable success with which they were used by the Parisians, in the late siege, to establish communication with the country in general, in defiance of a most vigorous blockade. We make no apology, therefore, for giving this part of our subject a more lengthy notice.

Soon after Montgolfier's and Charles's first trials the idea arose of using the aerostat, as the French have called it, for military purposes. At the siege of Condé, in 1793, an attempt was made to send news by a balloon across the investing lines; and about the same time, the celebrated Guyton de Morveau proposed to establish captive balloons as posts of observation in communication with the Republican armies. The idea was approved by the Committee of Public Safety, on the condition that sulphuric acid should not be used for the production of the hydrogen, all the sulphur obtainable being wanted for powder. Lavoisier got over the difficulty by his discovery of the decomposing action of red-hot iron on steam, and De Morveau's proposal was put in practice. A school of aerostatics was established at Meudon, and two companies of *aérostiers* were attached to the army. The campaign of the Sambre and Meuse was just then beginning, and an energetic young officer of the balloon corps, named Coutelle, was sent in all haste with two balloons to its aid. The General, who had received no notice of the step, at first treated the young man as a lunatic, and threatened to shoot him; but he was soon convinced of the importance of the invention, and adopted it without further hesitation. At the siege of Maubeuge and the battle of Fleurus, Coutelle rendered most important services in obtaining information as to the position and movements of the enemy, who afterwards made honorable testimony to the skill and ingenuity of the proceeding.

After this, military aerostation seems to have died away. The first Napoleon took balloons into Egypt, but the English seized the filling apparatus: his nephew had one made for the Italian campaign, in 1859, and appointed Garnerin as his aeronaut; but it only arrived the day after Solferino. We also hear of successful aerostation in the American Civil War a few years later, the signals being communicated to the earth by telegraph wires.

At the breaking out of the Franco-German War in July 1870, there were in Paris many experienced aeronauts, including Tissandier, De Fonvielle, Nadar, Jules Duruof, and Eugène Godard, the latter

* We must give a decided preference to the French edition of the work, not only because there are important omissions in the English copy, but because the style of the French authors, who are all practised writers, and express themselves forcibly and often eloquently, suffers much in translation.

of whom had made 800 ascents. The subject of military ballooning was mooted, and received some faint support from the Imperial Government; but before any thing of use could be arranged the disaster of Sedan occurred, and was followed in a few days by the close investment of the Capital. The new Government at once addressed themselves to the aeronauts, with the view of opening aerial communications with the exterior. Six balloons were found, all in indifferent condition, the worst being the Solferino one, 'L'Impérial,' which, M. Tissandier is careful to tell us, 'on n'a jamais su réparer.' The first ascent was made by M. Duruof on the 23rd September; he carried a large number of despatches, and landed safely in three hours near Evreux. He was followed on the 27th by M. Mangin; on the 29th, by Godard, jun.; and on the 30th by Gaston Tissandier, who has given an animated account of his voyage.

Encouraged by this success, the Government established the Balloon Post on a regular system, and took immediate steps for the manufacture of a large number of balloons, under specified conditions, and in the quickest possible time. It was easier, however, to make the vessels than to find captains for them, for experienced aeronauts were very few, and when they had once left Paris there was no returning. In this strait it was resolved to invite the help of sailors, a class of men whose training made them familiar with operations and dangers akin to those of ballooning. The appeal was well answered; many fine brave fellows offered themselves; they received such instruction as was possible, and a large number of ascents were conducted by them. 'Our topsail is high, sir,' said a tar to his Admiral, who saw him ascend, 'and difficult to reef; but we can sail all the same, and, please God, we'll arrive.' The employment of some acrobats from the Hippodrome was less fortunate, as they made use of their skill, when in difficulty, to slip down the guide-rope to the earth, leaving the passengers and despatches to take care of themselves.

The balloon service was on the whole conducted with remarkable success and precision. From September to January sixty-four balloons were sent off, and of these fifty-seven fulfilled their mission, the despatches reaching their destination. The total number of persons that left Paris was 155, the weight of despatches was 9 tons, and the number of letters 3,000,000. The speed of transit varied usually from about 7 to 40 or 45 miles an hour. In four cases a speed above 50 miles was attained, and in one instance about 80 miles; the high speeds being all with south-westerly winds.

We may mention some of the voyages which offer special interest. Gambetta left by the 'Armand Barbès' (every balloon had a name) on the 7th of October; being too low, he was fired on by the Prussians, and narrowly escaped being hit. On the 27th of October, the 'Bretagne' fell, by some bad management, into the hands of the Prussians near Verdun; on the 4th of November, the 'Galilee' had a similar fate near Chartres; and on the 12th the 'Daguerre' was shot at, brought down, and seized a few leagues from Paris. The loss of three balloons within a few days alarmed the Government; the vigilance of the enemy had been aroused, and whenever a balloon was seen, notices were telegraphed along its probable line of flight, and the swiftest Uhlans were put on the alert, with the hope of capturing it. Moreover, there was said to have arrived at Versailles a new rifled gun of enormous range, made by Krupp, to fire shell at the aerial messengers. On this account the Government determined that the future departures should take place at night. But the darkness added greatly to the difficulties of the voyage, and some of the ascents were attended with strange adventures.

On the 24th of November, near midnight, the 'Ville d'Orléans' left with an aeronaut and a passenger; the wind blew from the north, and it was hoped the balloon would fall near Tours; but before long the voyagers heard a sound below them which they recognised but too well as the lashing of breakers on the shore. They were in a thick mist, and when at daybreak this cleared away they found themselves over the sea, out of sight of land. They saw several vessels, and made signals for help, but were not answered, and one vessel fired on them. They were scudding rapidly to the north, and had given themselves up for lost, when they came in sight of land to the eastward. But they were descending from loss of gas, and their ballast was

gone; in despair they threw out a bag of despatches, and this saved them, for the balloon rose, and encountered a westerly current, which carried them to the shore. They had no idea what part of the world they were in; the ground was covered with snow, they saw no inhabitants, and being overcome by fatigue and hunger, they both fainted on getting out of the car. On recovering, they walked through the snow with great exertion, and the first living creatures they saw were three wolves, who, however, did not molest them. After a painful walk of several hours, they found a shed where they sheltered for the night, and the next morning, continuing their march, they came upon another hovel with traces of fire, which showed them the country was inhabited. Soon after two woodmen came in, but neither party could understand the other, and it was only by one of the peasants pulling out a box of matches marked 'Christiania,' that the Frenchmen could guess where they were. They had fallen in Norway. They were well received, and though the balloon had escaped when they fainted, it was ultimately recovered, with all the contents of the car, and the despatches reached their destination. The 'Archimède,' which started an hour after the 'Ville d'Orléans,' landed in Holland, after a voyage of seven hours.

The 30th November was a memorable day for the balloons. The 'Jacquard' ascended at 11 P.M., managed by a sailor named Prince, who cried out with enthusiasm as he rose, 'Je veux faire un immense voyage; on parlera de mon ascension.' He was driven by a south-easterly wind over the English Channel. He was seen by English vessels, and passing near the Lizard he dropped his despatches, some of which were afterwards picked up on the rocks; but the balloon, thus lightened, soared high over the wide Atlantic, and was never heard of more.

The 'Jules Favre' started at half-past eleven the same night with two passengers, and only escaped almost by a miracle the fate of the 'Jacquard.' The wind blew from the north, and the aeronauts thought they were going to Lyons; they were long enveloped in fog, and on emerging at daybreak they saw under them an island which they supposed to be in a river, but which proved to be Hoedic in the Atlantic! They were driving furiously out to sea; but in front of them lay, as a forlorn hope, the larger island of Belleisle. They saw they should pass one end of it where it was very narrow, and that they must either land on this strip of land or be lost. They tore the valve open with all their might, brought the balloon down some thousand feet in a few minutes, and fortunately succeeded in striking the land. But the shock was terrific; the balloon bounded three times, and at last caught against a wall, throwing both passengers out of the car. They were much hurt, but were hospitably received, singularly enough, in the house of the father of General Trochu.

On the 15th December the 'Ville de Paris' fell at Wertzlar in Prussia; and on the 20th, the 'General Chanzy' got also into captivity at Rothenberg, in Bavaria.

On the morning of the 28th January, the 'Richard Wallace,' which left Paris the night before, was seen at La Rochelle approaching the sea, and almost touching the ground. The people called to the aeronaut to descend, instead of which he threw out a sack of ballast, rose to a great height, and soon disappeared in the western horizon. No doubt the poor fellow had lost his wits on seeing the danger before him. This was the last ascent but one; that on the next day carried to the provinces the news of the armistice.

The balloons had solved the problem of communication from Paris outwards, but there was another, not less important, namely, how to obtain a return communication inwards from the exterior. This was a much more difficult matter; any wind would blow a balloon away from the city, but to get one back again required a particular direction of current, with very little margin. M. Tissandier devised some ingenious schemes, and himself made several attempts to get back, but failed, and the return of balloons was given up as impracticable.

Failing these, other modes were thought of, and the Government appealed energetically to men of science and inventors to help them in their difficulty. Numberless projects were offered, and a committee sat *en permanence* to examine them, but the great majority were wild and visionary.

A few trusty foot messengers succeeded in penetrating the Prussian lines, and

many cunning devices were invented for concealing about them short despatches in cypher; hollow coins, keys, and other articles of unsuspicious appearance were skilfully prepared; occasionally a despatch was inserted in an incision under the skin, and one of the contrivances most successful, till an indiscreet journal let out the secret, was an artificial hollow tooth. One balloon took out some trained dogs, which it was hoped would find their way back again, but they never reappeared. A daring attempt was made, by some electricians, to connect the broken ends of the telegraph wires (which had of course been cut) by almost invisible metallic threads, but they could not succeed. The river, flowing into Paris from the plains of central France, formed the basis of many promising schemes. Divers, submarine boats, and floating contrivances of many kinds were proposed, and some of them tried; the most ingenious being little globes of blown glass, so marvellously resembling the natural froth bubbles on the surface of the water as to escape the most vigilant observation. It was thought at one time that these would come into use, but before the 'service des bulles' could be organised, the frost set in, and spoiled the surface of the river.

The problem which had defied the ingenuity of man, was, however, solved by the instinct of a bird. The return post was effected by means of *carrier pigeons*, which, having been taken out of Paris in balloons, were let loose in the provinces to find their own way home. There existed in Paris a 'Société Colombophile,' and after the departure of the first balloon, the Vice-President waited on General Trochu, and proposed that an attempt should be made to combine the outward balloon post with a return service by pigeons. The second balloon carried three birds, which came safely back six hours afterwards, with news from the aeronauts; and the return of eighteen more despatched in following days confirmed the practicability of the plan. The service was then regularly organized, and was carried on with more or less success during the whole of the siege.

But though the messengers were found, it was necessary to give careful attention to the mode of transmitting the messages. A pigeon's despatch is tied to one of the feathers in his tail, and, of course, in order to avoid impeding his motion, it must be very small and light. For strategic purposes, small dispatches in cypher would have sufficed, but the Government, with laudable spirit, wished to give the public the benefit of the pigeon post, as they had already done with the balloon service, and this gave rise to one of the most remarkable and ingenious postal arrangements of the siege, namely the application of *microscopic photography*.

The exquisite delicacy of the colloiond film had long been known, and with the aid of a microscopic camera, pictures had been produced on it which, though so small as scarcely to be visible to the naked eye, exhibited, when magnified, all the details of the original. M. Dagron,* who had practised this art, pointed out its applicability to the pigeon post, and was commissioned to organize the arrangements. He left in the 'Niepce' balloon on the 12th November, and, after falling into the hands of the Prussians at Vitry-le-Français, he escaped to Tours, where, and at Bordeaux, he conducted the process with much success.

The despatches, public and private, were first printed (to save space and render them more legible) on pages of folio size, sixteen of which were placed side by side, forming a large sheet about 54 inches long and 32 inches wide. This was reduced by photography to $\frac{1}{800}$ of its original area, the impression being taken on a small pellicle of transparent gelatinous collodion, 2 inches long and $1\frac{1}{4}$ inch wide, and weighing about three-quarters of a grain. The figure in the margin is a full-sized representation of one of these pellicles now before us. The sixteen pages of letter-press will be seen in their reduced size; each page consists of about 2000 words, and, therefore, the whole impression contains as much matter as sixty-five pages of this review.

We have read the despatch with a powerful microscope, and find it contains a great number of messages, chiefly of personal interest, to inhabitants of Paris, from many parts of France. We extract the following as samples:—

'*Dépêches à distribuer aux destinataires.*

'*Pau, 26 Janvier.*—À Focher, Rue Chaussée d'Antin. Madeleine accouchée heureusement hier. Bien beau garçon.

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* 'La Poste par Pigeons Voyageurs.' Par Dagron. Tours, Bordeaux, 1870–1.

'*Biarritz*, 1 *Février*.—A Martin, 68, Rue Petites Écuries. Sommes à Biarritz, bébé complétement remis, embrasse papa, douloureusement impressionnés événements.

'A Font. Besoin argent, demande Masquier.

'A Perier. Tous parfaitement bien; trouveras charbon dans cave.'

There are also many 'Dépêches Mandats,' or post-office orders, payable to persons in Paris, from correspondents in the country.

Every pigeon carried twenty of these leaves, which were carefully rolled up and put in a quill; they contained matter enough to fill a good-sized volume, and yet the weight of the whole was only fifteen grains. When the pigeon arrived at his cot in Paris, his precious little burden was taken to the Government-office, where the quill was cut open, and the collodion leaves were carefully extracted. The next process was to magnify and read them by an optical apparatus, on the principle of the magic lantern, or rather of the well-known electric illustrator, which plays such an important part in the scientific lectures at our Royal Institution. The collodion film was fixed between two glass plates, and its image was thrown on a white screen, enlarged to such an extent that the characters might be read by the naked eye. The messages were then copied and sent to their destination.

The despatches were repeated by different pigeons, for although the communication was established many causes interrupted its regularity. The Prussians were powerless against the winged messengers (it is said they attempted to chase them with birds of prey); but there were more real obstacles in fogs, which prevented the pigeons seeing their way, and in the great cold, which was found to interfere with their powers, particularly when the ground was covered with snow. There were sent out of Paris 363 pigeons, but only 57 returned, and some of these were absent a long time.

The charge for private despatches by pigeon was 50 centimes per word; but to facilitate the service, the Parisians were directed to send to their friends in the country, by balloon, questions which could be answered by pigeon with the single words, 'Yes' or 'No.' Forms were prepared, something like our postage-cards, and four such answers were conveyed for one franc.

The Parisians will long recollect the excitement produced by the arrival of their pretty couriers; no sooner was a pigeon seen in the air than the whole city was aroused, and remained in a state of intense anxiety till the news was delivered. An engraving was afterwards published representing Paris, as a woman in mourning, anxiously awaiting, like Noah's imprisoned family, the return of the dove.

The aerial post was undoubtedly a great success. It could not indeed save France, or deliver the Capital; but it was an immense comfort and advantage to the Parisians as establishing, during the whole of the siege, a correspondence with the exterior, which without it would have been impossible. And had the cause been less desperate, it is not improbable that the balloons might have turned the scale, by giving to the French substantial advantages in their means of communication.

We must now, in conclusion, say a few words on the general capabilities and prospects of the balloon as a means of aerial locomotion. The problem is one of great interest and importance; for it need hardly be said that if such a mode of transit could be established, its advantages would be almost incalculable.

The balloon already fulfils, as we have seen, one of the two necessary conditions; it will float in the air, and it can be made to rise and fall at pleasure.* But it fails in the second particular. The great obstacle at present to its use is the want of power over the *direction* of its flight. It is at the mercy of the wind, which 'bloweth where it listeth;' and a vehicle which can only travel to some unknown place is not likely to have many business passengers.

It has often been proposed to take advantage of the fact, well ascertained by

* The present mode of doing this, involving a continual loss of gas and ballast, and a consequent waste of ascending power, is very imperfect; it was one of Mr. Green's objects, in the invention of the guide-rope, to ameliorate the evil, by providing a kind of ballast which could be discharged temporarily, and taken in again; and no doubt this expedient, combined with a perfectly impermeable envelope, would much extend the limit of balloon voyages. There is, however, great room for improvement in this particular.

experience, that currents are found, at different heights, moving in different directions; but the information on this point is at present very imperfect; and probably such a mode of direction would be always uncertain. The more important problem is, how to make a balloon travel, not *with*, but *through* the air; in the same manner as a boat, instead of being floated along with the stream, is made to move in an independent course through the water. In short, we want what, if we may coin a word for the purpose, we may call a *dirigible* balloon.

The Montgolfiers, in 1783, discussed the use of oars, and Guyton de Morveau, in the following year, made some experiments at Dijon with analogous contrivances. But no useful result was obtained, and the question does not appear to have been studied, with any earnest attention to its mechanical conditions, until the middle of the present century.

The nature of these conditions may best be learnt by considering the analogous case of a boat; not a sailing boat which is moved by external power, but a rowing boat or a steamer in which the power is internal. In such a vessel the motion is produced by oars, paddles, or screws, the surfaces of which are impelled against the circumambient fluid by mechanical power; the reaction sends the vessel forward, and when the motion through the fluid is once obtained, the *direction* is determined by that simple and beautiful contrivance, the rudder.

According to this, in order to make our balloon move through the air, it must be provided with propelling apparatus, propelling power, and a rudder. And, as a further condition, derived from aquatic analogy, it must have such a form as will offer the least resistance in its passage through the air. If these conditions are complied with, we shall certainly get a dirigible balloon, and they involve nothing that is at variance with mechanical knowledge, or that is beyond the scope of mechanical skill.

The first good attempt to make such a balloon was in 1852 by a French engineer, M. Henri Giffard. He was then young and unknown, but his name has since become famous on other grounds. He had evidently studied the subject well, and had arrived at a thoroughly practical appreciation of the necessary conditions. Abandoning the globular shape, as offering too much resistance, and following the analogy of the lines of a vessel, he constructed an oblong pointed balloon, to the stern of which he attached a rudder, and in the car he carried a small steam-engine, which worked a screw, formed of sails like a wind-mill. It was about 150 feet long, and 40 feet diameter. It contained 88,000 cubic feet, and was filled with coal-gas. The engine was three-horse power, weighing 3 cwt., and it turned the screw 110 revolutions per minute. It was a daring thing to put the furnace of a steam-engine so near to a huge reservoir of highly inflammable gas; but M. Giffard adopted, among other precautions, the ingenious device of turning the chimney *downwards*, producing the draught by the steam-blast, as in the locomotive-engine; and he considered himself free from any danger of fire.

The ascent took place from the Hippodrome in Paris on the 24th September, the signal to 'let go' being given by the steam-whistle. The wind was strong, and M. Giffard did not expect to hold against it; he found, however, that he could make a headway through the air of five to seven miles an hour; and this enabled him to execute various manœuvres of circular motion with perfect success. The action of the rudder was very sensitive. No sooner, he says, did he pull gently one of the cords, than he saw the horizon turn round him like the moving picture in a panorama. He rose to a height of nearly 6000 feet, but, the night approaching, he put out his fire, and descended safely in a field near Elancourt.

In 1855 M. Giffard constructed another balloon, of larger dimensions, which confirmed the previous results; but he found that before the direction could be completely commanded, many improvements were necessary which would take time. His attention was just then occupied on other mechanical inventions,* but he did not neglect the subject, for, in the great captive balloons erected by him in 1867 and 1868, he perfected several of the improvements he had in contemplation, in particular the impermeability of the enve-

* M. Giffard has acquired great fame by his invention of the 'Injector,' an apparatus now applied almost universally to locomotives, and which is one of the most remarkable and novel applications of science to engineering.

lope, a more mechanical construction of the valves, and a better and cheaper mode of preparing pure hydrogen.

During the siege of Paris, the earnest desire to get a return-post to the city again called attention to the subject of dirigible balloons. In October 1870, M. Dupuy de Lôme, the eminent Naval Architect to the French Government, obtained a grant of sixteen hundreds pounds for experiments, and he proceeded to construct an apparatus, which was in progress when the Communist insurrection broke out and stopped the proceedings. On peace being restored, M. de Lôme resumed the work at his own cost, and the trial was made on the 2nd of February, 1872. He has given a full account of his proceedings in several papers of the 'Comptes-rendus' of the Academy of Sciences. His balloon was elongated, 120 feet long, and 50 feet diameter, containing 122,000 cubic feet, and it was filled with hydrogen. It had a triangular rudder, and the car carried a screw-propeller of two sails, 30 feet diameter, intended to be turned by four men, a relay-gang being also taken up to relieve them. M. de Lôme considered it essential that the balloon should preserve its form in spite of any escape of gas, and, to ensure this, he placed, inside the large envelope, a smaller balloon, which could be filled with air from the car when required.

The ascent took place at Vincennes, with M. de Lôme and thirteen other persons in the car. In the early exposition of his objects he had stated that he did not aim at attaining any great independent speed; the important point was to get such a moderate control over the course as should render it possible for balloons to return into Paris, and he believed that a motion through the air of about five miles (eight kilometres) per hour would suffice for this purpose. Soon after leaving the ground the screw was put in motion, and, on the rudder being taken in hand, its influence was at once observable. The wind was high, blowing from the south-west, with a velocity varying from 27 to 37 miles an hour, and all that could be hoped for was to produce a moderate deviation in the direction of the flight. This was accomplished, as, when the screw was put to work, and the head of the balloon set at right angles to the wind, a deviation was obtained of ten or eleven degrees, showing an independent motion through the air of 5 to $7\frac{1}{2}$ miles an hour, produced by the machinery. The descent was made safely about 90 miles from Paris.

As a matter of fact, M. Dupuy de Lôme does not seem to have accomplished much beyond what M. Giffard had done previously: and it is to be regretted that both M. Giffard and he should have left the subject where it is; but fortunately, guided by the data obtained, we may form an idea, much more satisfactory than heretofore, of the position of the question, and of the prospects of the invention for the future.

In the first place, the possibility of constructing, on principles analogous to those of aquatic navigation, a buoyant aerial screw ship, which shall have a form of small resistance, which shall be stable and easy to manage, and which shall obey her rudder, has been fully established; there only remain the questions what power is necessary to give such a vessel a certain speed through the air; what amount of power can be carried; and how that power may be applied.

The relation between power and speed has been carefully investigated by M. de Lôme on sound mechanical principles, checked by the actual data of aquatic navigation, and although their application to this problem is new, they seem to have been confirmed by experiment so far as the limited trial extended. M. de Lôme calculated beforehand that to give a speed of five miles an hour would require a net expenditure of about $\frac{3}{10}$ths of a horse-power;* for which, allowing for loss, he allotted 4 men, or $\frac{4}{10}$ths of a horse-power. In the actual experiment he found that 8 men (or $\frac{8}{10}$ths of a horse-power net) gave

* The power required to propel the balloon depends largely on the value of the coefficient representing the reduction of resistance due to the form or to the *lines* of the vessel. There is little experience of this for the air, but M. de Lôme asserts by the analogy of ships, that it may be as low as $\frac{1}{40}$ or even $\frac{1}{30}$. Allowing for resistances of the car and net, and for other defects, he has in his calculations brought it out at a mean value of $\frac{1}{10}$; and adopting this, we have the following formula. If d = largest diameter of balloon in feet, and v = velocity through the air in miles per hour, then the net horse-power required will be in round numbers—

$$\text{H. P.} = \frac{d^2 v^3}{1{,}000{,}000}$$

6·4 miles per hour, which is sufficient confirmation, the power varying, according to a well-known rule, as the cube of the speed. Hence to give 10 miles an hour would require 2½ horse-power, 20 miles 20 horse-power, and so on.

The form of power adopted by M. de Lôme, namely human effort, involved an enormous waste of weight; and in reasoning on what may be done, we have a right to assume a more economical arrangement. A horse-power in the shape of 10 men, with a relay of 5, weighs above a ton; but in the steam engine this may be reduced very largely. M. Giffard's engine and boiler weighed 112 lbs. per horse-power; in some boats lately working on the Thames* the weight was only 60 or 70 lbs., and in other instances it has been reduced still lower.

To keep up the power, we may estimate that the engine will require, per horse-power per hour, 3 to 5 lbs. of fuel and 25 to 28 lbs. of water. But, by an ingenious 'air surface condenser,' lately introduced by Mr. Perkins, the water evaporated may be recovered and used over again, and M. Giffard has pointed out that the fuel and water lost would take the place of the ballast usually put in the car.

We should be quite within actual practice in estimating for each horse-power, 100 lbs. weight of engine, boiler, and condenser, and 10 lbs. for each hour's consumption. Hence, as M. de Lôme's balloon had, after allowing for his entire apparatus and machinery, about 4600 lbs. disposable buoyancy, we find he could carry a 20-horse engine, and keep up a speed of 20 miles an hour for 13 hours. By enlarging the balloon, say to 100 feet diameter, we should get an available buoyancy of 20 tons, which would enable a speed of 20 miles an hour to be kept up for 24 hours, and still leave some 7 or 8 tons free.

These calculations are formed, be it observed, on data already existing; we have made no allowance for the improvements that would naturally arise when the attention of ingenious men was drawn to the subject, and when actual experience had been gained. The application of high power would doubtless require many alterations in construction, and much study of detail, and there is every probability that in the course of this study by skilful engineers such ameliorations would be brought about as would result in the attainment of higher speeds than we have above taken credit for.

Let us only, for the sake of argument, assume that we could attain for our balloons an independent velocity of 25 miles an hour through the air; it is worth while to inquire what that would do towards the solution of the great problem of aerial locomotion.

We have here to consider the effect of the wind. According to the best tables, what may be called an ordinary breeze blows between ten and twenty miles an hour, a strong breeze between twenty and thirty, a high wind between thirty and forty, and a gale up to fifty or more. The average velocity of balloons carried along by the wind has been found to be about twenty-five miles an hour, and we may fairly assume that the current is as often below as above this velocity. Hence it follows that for half the days in the year we might have the power, by properly constructed dirigible balloons, of navigating the air as we pleased, in any direction. If the wind were for us, we should make thirty to fifty miles an hour; if against us, we should go slowly, but, as the French sailor said, 'Please God, we should certainly arrive.' In the other half of the year, when the wind exceeded the velocity we could command, we must give up the idea of steaming against it; but even then our steering power would give us very great advantage in deviating from the wind's direction. An example will make this clear. Suppose that a high wind were blowing from the west, with a velocity of forty miles an hour (the highest, perhaps, that it would be prudent to attempt a voyage with), we could not go anywhere westerly, or even due north or south, but, by the aid of our independent speed of twenty-five miles, we could command any course we pleased between north-east and south-east, giving us still a very large and useful range; and what we lost in this respect we should gain in swiftness, as our velocity running east would be sixty-five miles an hour.

Then one most important use of dirigibility would be in facilitating the descent, and in avoiding the many dangers to which the aeronaut, in his present helpless

* 'Trans. Inst. of Naval Architects,' 1872, p. 269. Paper by Mr. F. J. Bramwell, F.R.S.

position, is so often exposed. He could choose his place of landing with precision, bearing right or left at pleasure, and, turning his head to the wind, he could get rid of, or largely diminish, the dragging which is so dangerous, and which has so often brought a fatal termination to balloon voyages. Indeed, with ordinary precautions in the construction and management of the apparatus, a dirigible balloon would furnish one of the safest, as well as one of the swiftest and pleasantest, modes of locomotion.

And, further, it must be borne in mind that the increased frequency of balloon voyages would lead to a more careful practical study of the atmospheric conditions bearing on them. We may, indeed, conclude that the future use of balloons will probably depend on a moderate steering facility, combined with the power of taking advantage of the best circumstances of wind and weather; and we do not doubt that with such a combination, well studied, and wrought out with the skill of which the present age is capable, the balloon has the power to become a really useful machine.

We have had no space in this article to speak of flying. There are many students of aerial locomotion who profess a contempt for the balloon, as a mere plaything, and consider that the only proper solution of the problem is by a flying machine, which shall sustain itself in the air, like a bird, by mechanical means. They disdain floating power, which, they say, birds do not possess, and which is, therefore, unnecessary. It would be just as reasonable to propose, on analogous grounds, to abolish boats and substitute swimming-machines. The 'plus lourd que l'air' doctrine is a delusion, founded on the mechanical blunder of confounding gravity and momentum, which are two distinct things. It is a more reasonable objection that a balloon, from its large size, must offer a great resistance to the air at high speeds, but this resistance has been enormously overrated,* and it is a cheap price at which to acquire the fulfilment of the first condition of aerial locomotion—that of overcoming the action of gravity. At all events, a dirigible balloon is a thing actually in existence; a flying-machine is, at present, only an idea.—*Quarterly Review.*